Sustainability in Remediation

CRG Brown Bag

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DuPont Engineering

Brandt Butler and Jason Chen
URS Diamond

October 30, 2006

Rev 10-29a


AND NOW
FOR SOMETHING
DIFFERENT

Agenda

12:00 **The Case for Remediation Sustainability – Dave Ellis**

12:20 **Remediation Sustainability – Brandt Butler and Jason Chen**

- Methodology
- Examples
- Site X

12:45 **Path Forward – Dave Ellis**

12:50 **Open Discussion**

Some Observations on Cleanups

Cleanups consume large amounts of money, time, and resources and accomplish little risk reduction

Few cleanup technologies work. Those do not work in a lot of places

Science tells us that cleanup rates are limited by diffusion and desorption, some cleanups take centuries

Cleanups emit CO_2 and other greenhouse gasses, send a lot of material to landfills, occupy substantial number of worker hours, etc., etc…

Dirt is constantly being buried and permanently lost in landfills. Why?

Surely we can do better!

Sustainability and Cleanup Methods

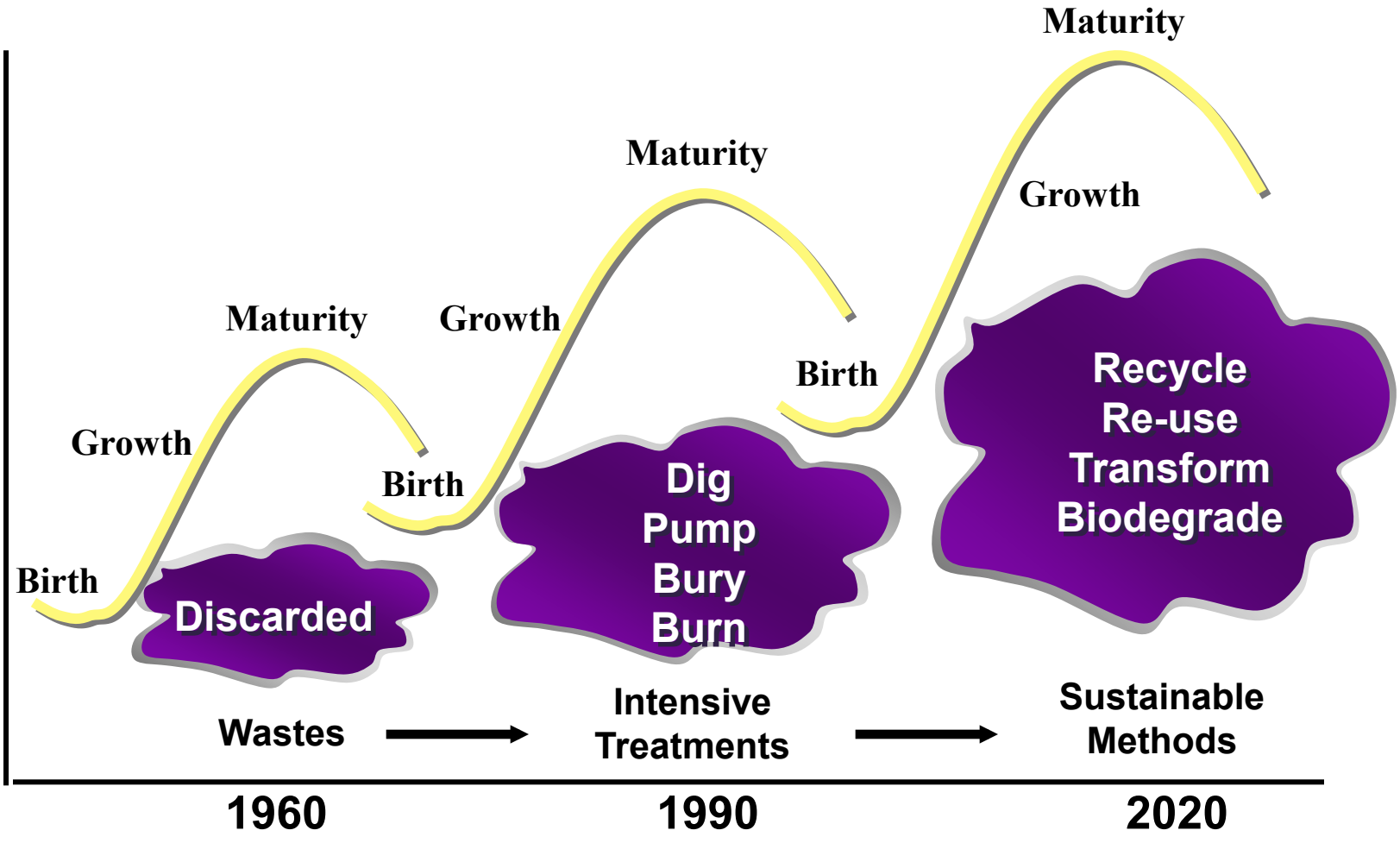
DuPont is trying to learn how we can connect sustainability and remediation

If a cleanup will take centuries, DuPont wants to be certain to use the most sustainable methods we can identify, and suggests that more sustainable cleanup methods should be given priority.

Selecting a sustainable remedy considers: protecting HH&E, global warming, recycling, resource preservation, waste generation, safety, etc…

However, without a common language or system of measurement, these claims will be confusing.

How Can We Transform Our Thought Process?



DuPont's Earlier Sustainability Actions

We emphasized using recycled materials to build remedies

We substituted wastes for reagents in building cleanups

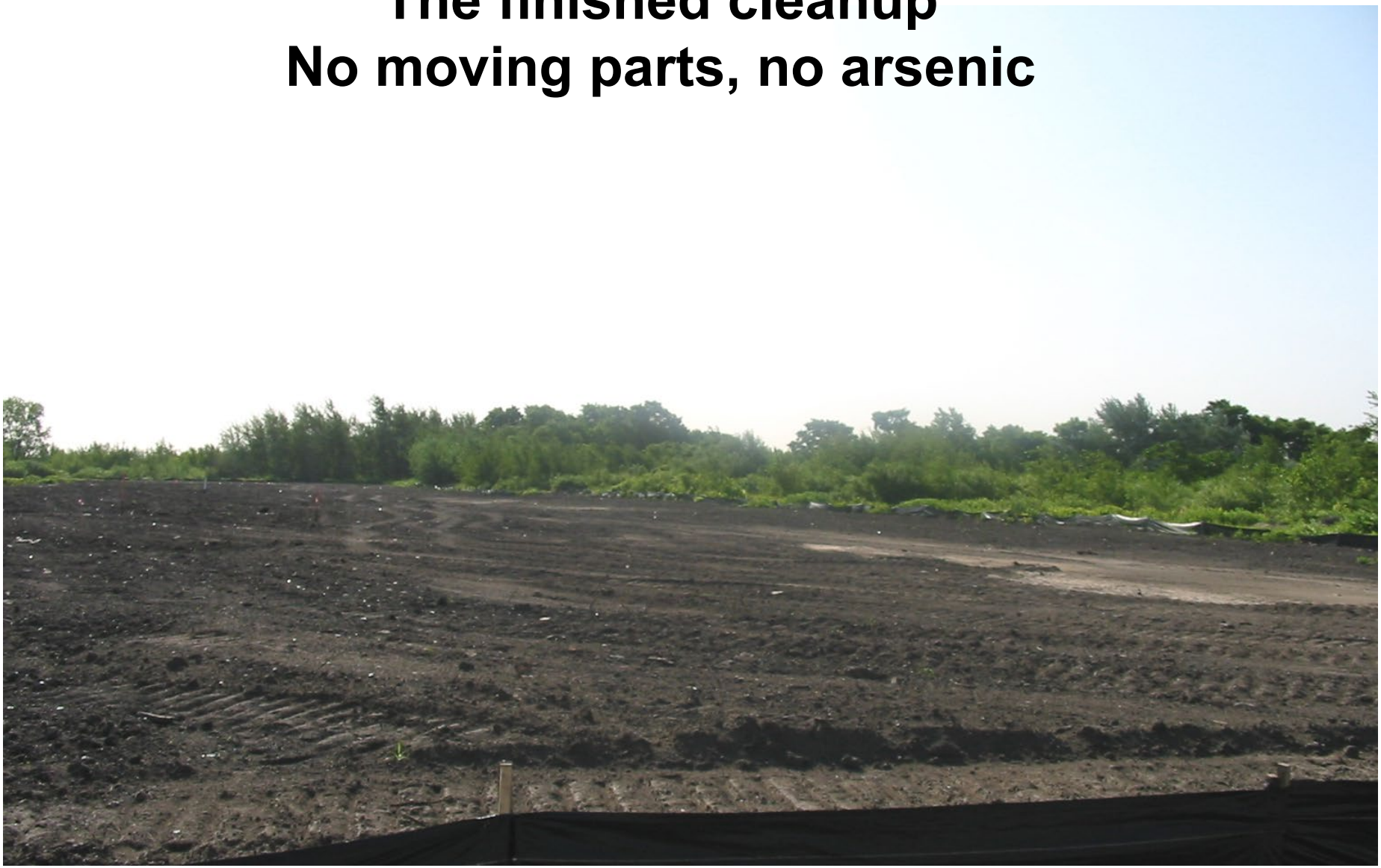
Three examples which won awards:

- Ferdula, NY – Wind powered remediation
- East Chicago, IN – slag to clean up arsenic
- Newport, DE – iron grinding chips, gypsum from WWT

Wind Powered Remediation

A 30’ x 2,200’ trench with 43,000 tons of slag cleans up arsenic

The finished cleanup
No moving parts, no arsenic



Sustainable Remediation Principles

Our working concepts:

DuPont, in fulfilling its obligation to remediate sites to be protective of human health and the environment will embrace sustainable approaches to remediation that provide a net benefit to the environment.

To the extent possible, these approaches will:

- Minimize or eliminate energy consumption or the consumption of other natural resources;
- Reduce or eliminate releases to the environment, especially to the air
- Harness or mimic a natural process;
- Result in the reuse or recycling of land or otherwise undesirable materials.

Two Characteristics Types of Sustainable Remedies

Remedies that permanently eliminate a contaminant from soil, water, air volumes, e.g.

- **Soil washing**
- **Oxidation/reduction**
- **Biodegradation**

Remedies that provide other "green" benefits relative to other remedies, e.g.

- **Lower CO_2 production**
- **Use renewable resources**
- **Designed and operated to optimize long-term net environmental benefits**

These approaches are not mutually exclusive

Thinking Differently About Cleanups

Similar to life cycle analysis

Understand each major task

Define the major inputs and outputs

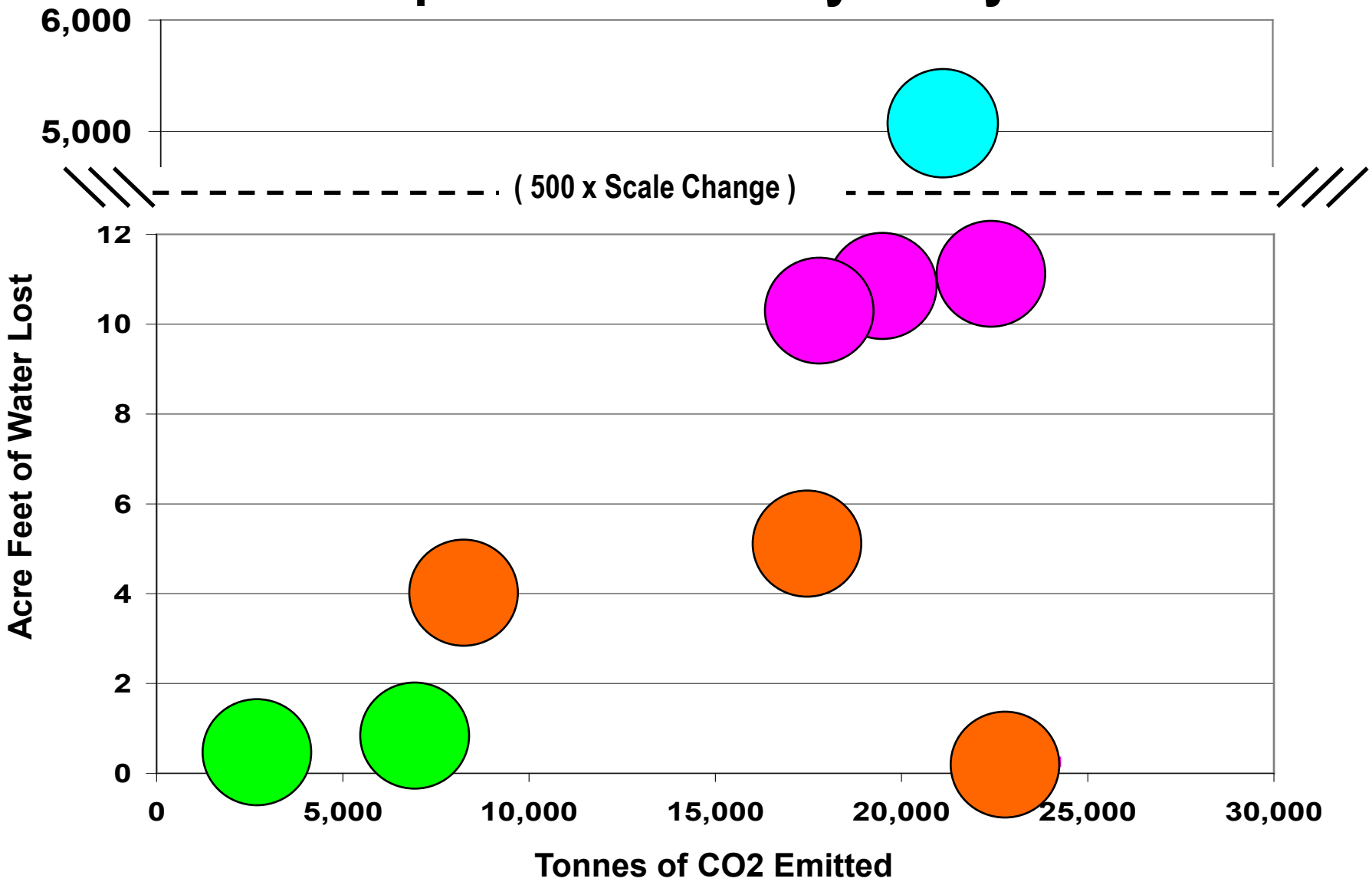
Think resources instead of contaminants

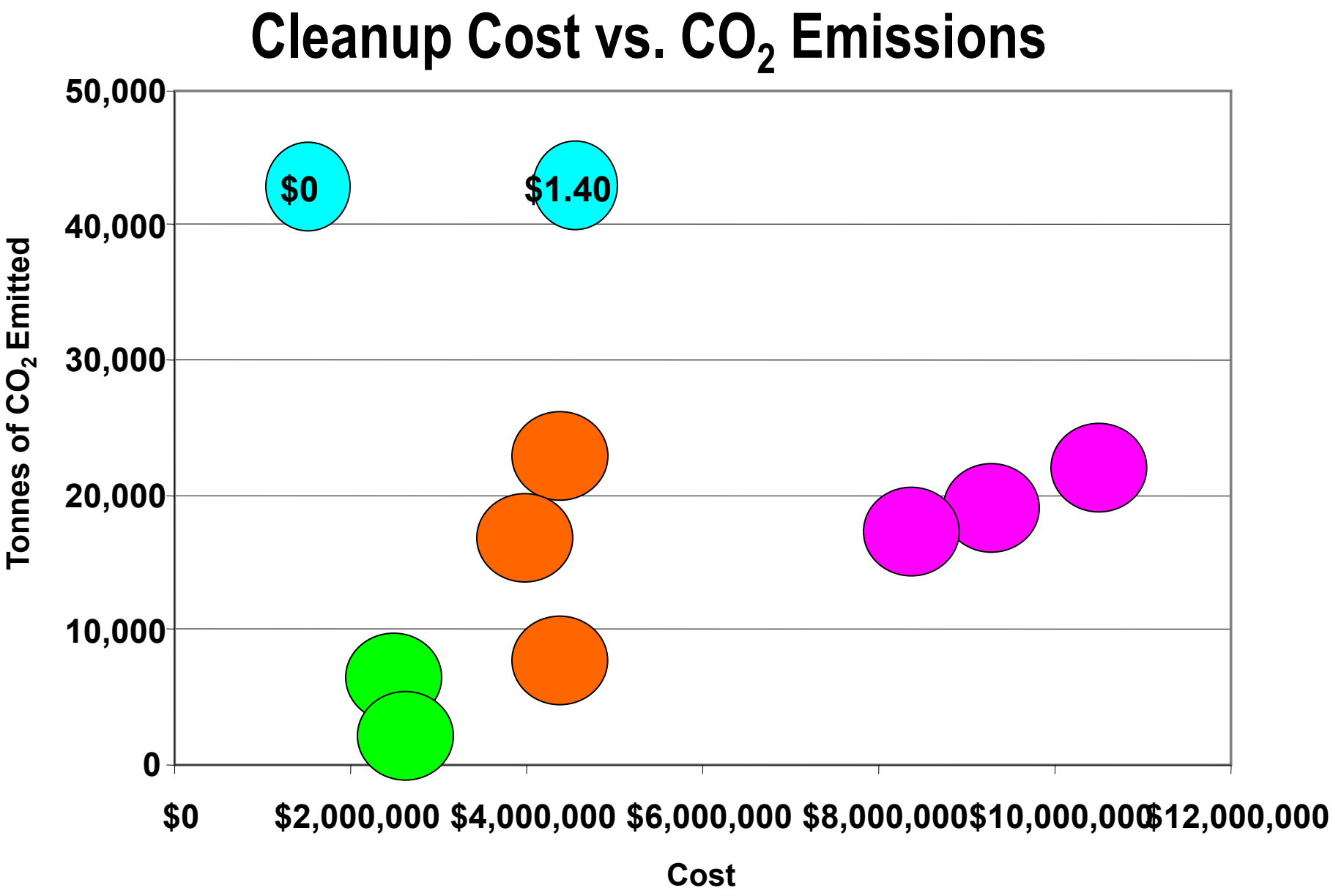
Sum up those you can identify

Don’t over analyze – it’s dark underground

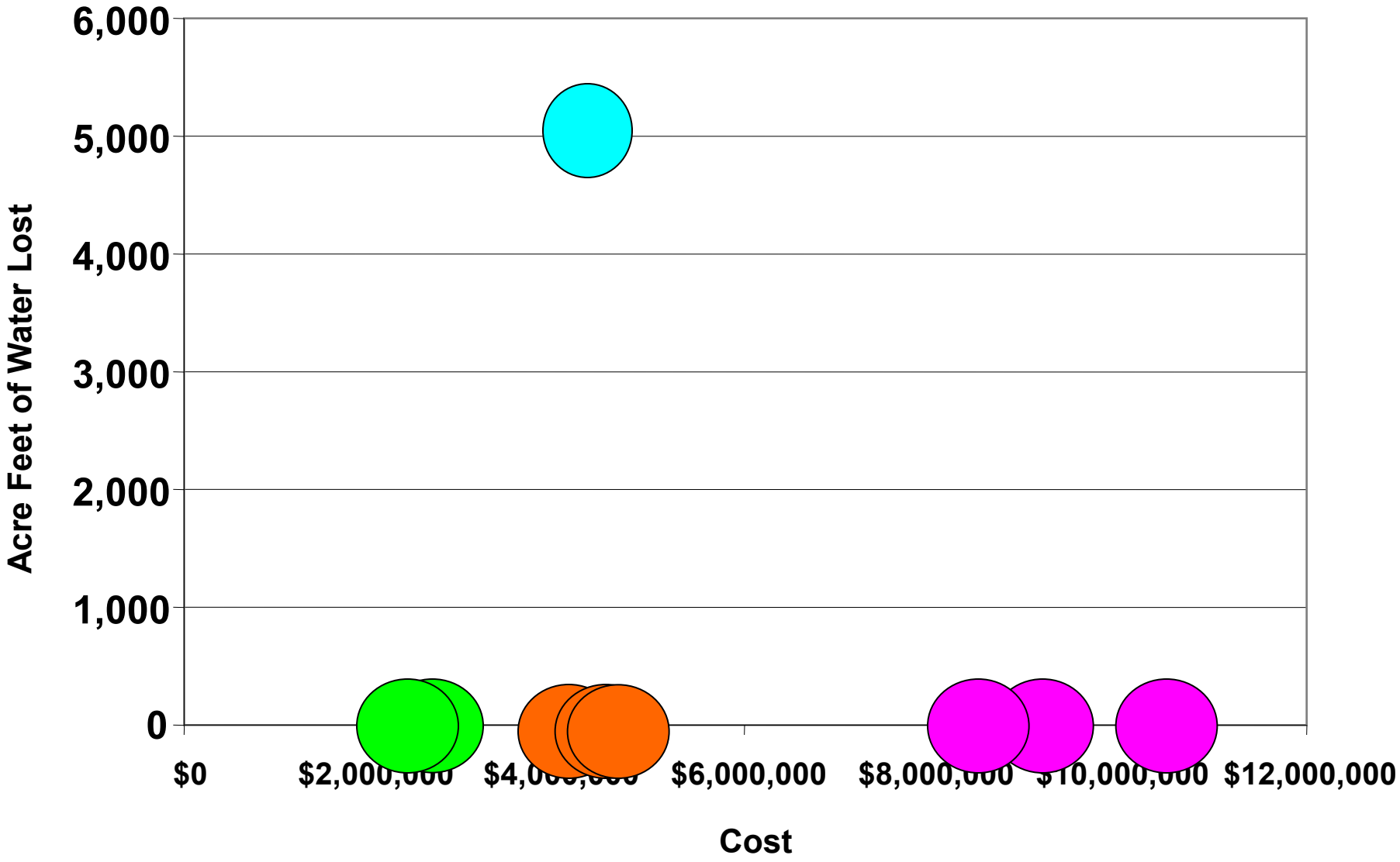
The process of thinking differently changes perspectives and leads to less expensive yet more effective solutions

Example Sustainability Analysis

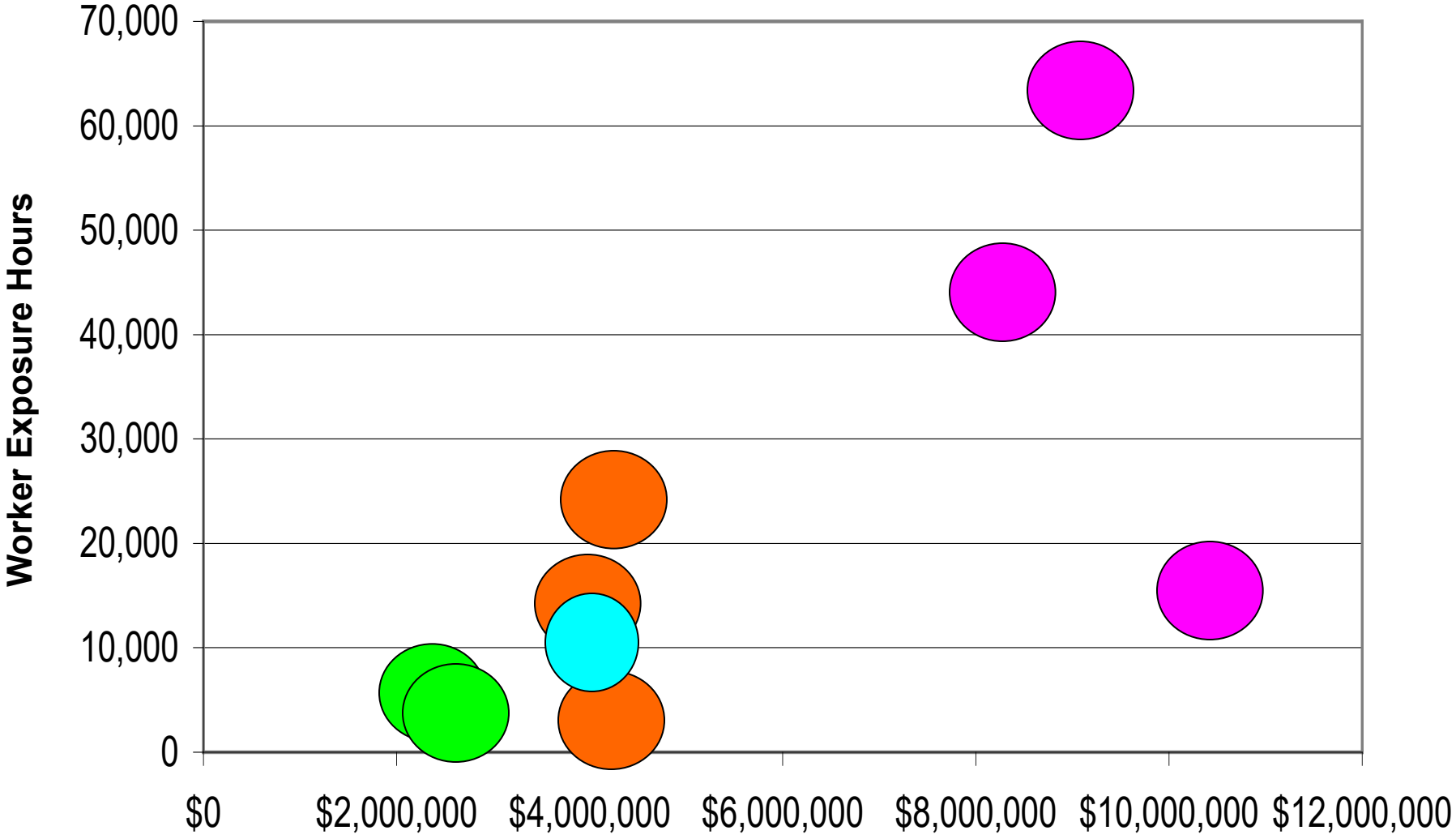



Cleanup Cost vs. CO_2 Emissions
50,000
40,000
30,000
20,000
10,000
0
Tonnes of CO_2 Emitted
$0
$1.40
$0
$2,000,000
$4,000,000
$6,000,000
$8,000,000
$10,000,000
$12,000,000
Cost

Cleanup Cost vs. Water Loss



Cleanup Cost vs. Exposure Hours



Making Remediation Decisions

	Safety	Risk Reduction	Regulatory	Public Relations	Liability	Technical	Implement-ation Cost	Sustainability	
General Objectives:	Minimize H&S exposure	Protect human health and the environment	Control off-site COC migration, plume stability	Maintain positive relationships	Eliminate / minimize	Long-term effectiveness no O&M	Minimize Cost	Net Benefit to the Environment	Scoring Results
Option A	5	1	1	1	1	1	5	3	18
Monitoring	Minimal exposure	Likely not acceptable long-term	Does not control migration or stability	May be viewed as not responsive to problem	No immediate impact, liability may increase	Not effective in reducing mobility, toxicity or volume		CO2 emissions minor	
Option B	3	5	4	5	5	3	3	2	30
Downgradient Control	Some exposure during installation and operation	Acceptable at POE short and long-term	Plume migration control, may not control stability	Highly visible, may have postive short-term results	Positive impact, off-site migration is curtailed	Reduces mobility, toxicity, not volume		CO2 emissions 8,500 tons, minor recycling	
Option C	3	5	5	4	3	5	4	1	30
Source Control	Some exposure during installation and operation	Acceptable throughout long-term	May have longer-term effect on migration and stability	Highly visible, results may be longer-term	Longer-term, positive impact on liability	Reduces mobility, toxicity and volume		CO2 emissions 50,000 tons, significant landfilling	

* Note: Scale is based on 5 to 1, where 5 is the most positive impact on each category while a 1 represents the most negative impact.

Financial Impact of Considering Sustainability

Sustainability analyses drive you toward remedial actions that have lower energy use, lower off-site transfers, and lower labor hours

All of these contribute to selecting lower-cost remedies as well as remedies with low external impacts

Using natural processes leads to technologies such as MNA, biodegradation, and in-situ technologies

What Is DuPont Going to Do About This?

Pursue a sustainable remediation program

Develop internal methods and standards

Engage external customers and stakeholders, including regulatory agencies and other companies

Measure our performance

- **emissions**
- **acres of land raised to their highest practical level of re-use**
- **volume of hazardous material sent to landfills**
- **mass of contamination removed from the environment**
- **remedies evaluated for sustainability**

Recycle land

External Engagements

Engage external customers and stakeholders, including regulatory agencies and other companies

• AHC	June 22
• EPA	June 27
• SABRE	September 12
• Chambers Works SAB	September 26
• NJ DEP	October 5
• Honeywell	October 10

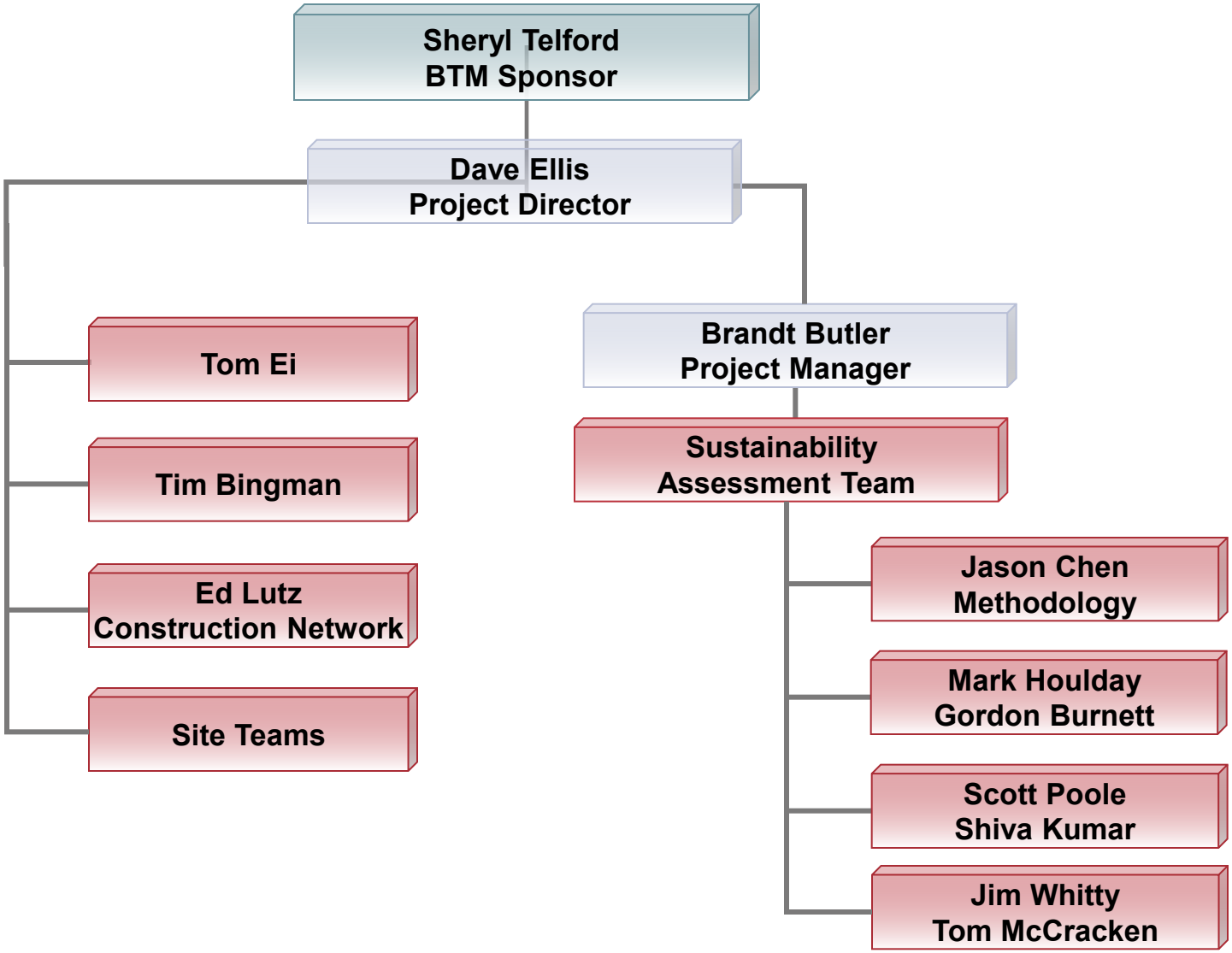
- Open sustainability meeting November 13 or 15. Invitees include:

Companies:	GE, Dow, PSEG, Chevron, Shell, GeoSyntec
Academics:	NJIT, British Geological Survey
Government:	EPA, DoD, UK EA, NJ DEP, CAL EPA
NGO's:	Environmental Defense

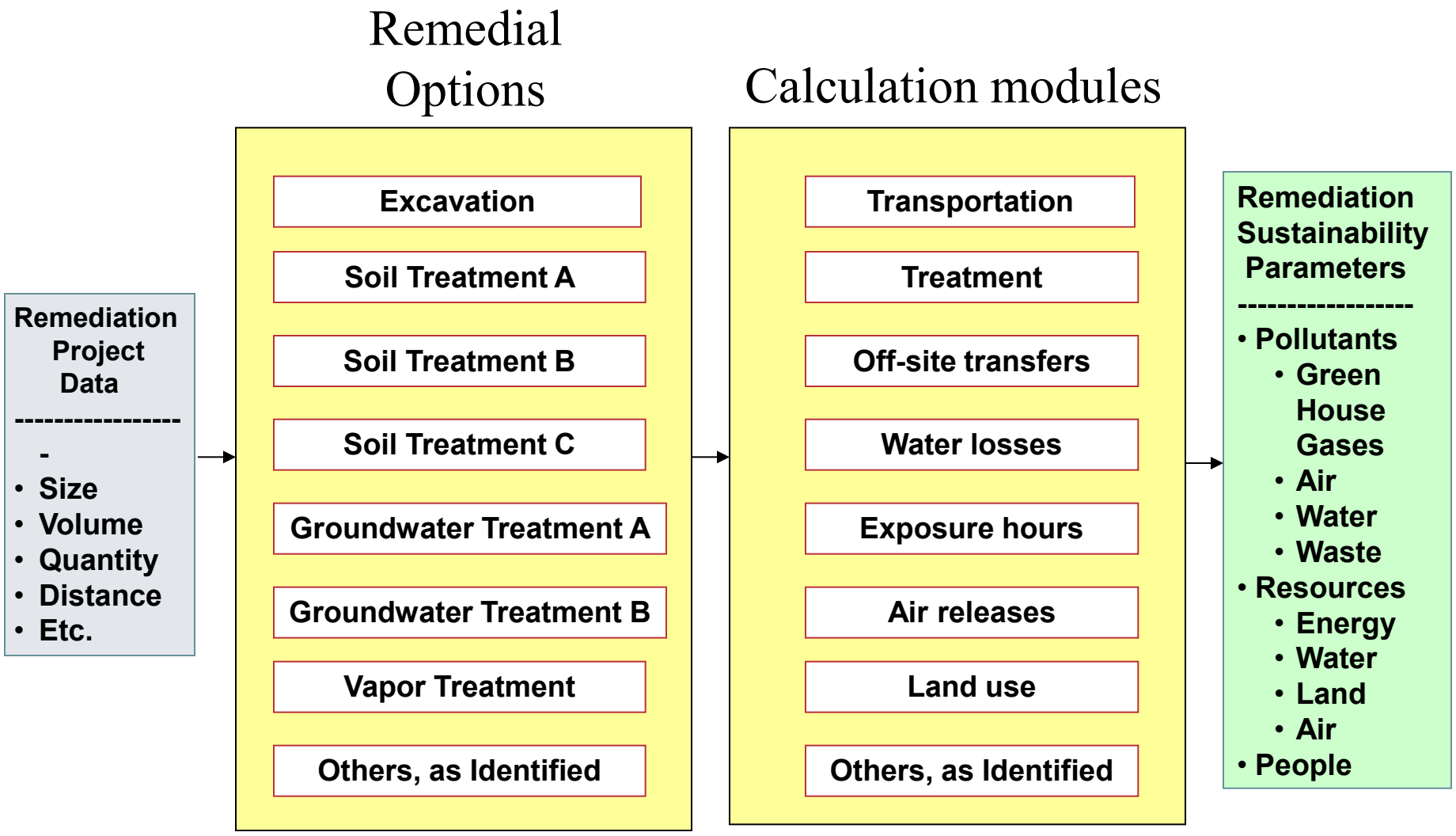
Remediation Sustainability

- Conceptual Framework
- Evaluation Methodology
- Site Assessments
- Hypothetical Site X

CRG Sustainability Team



Conceptual Framework for Sustainability Analysis



Creating the Modules

- **Is there an existing evaluation for a similar process?**
- **Revise or create new module(s) by revisiting assumptions and calculations**
  - Different processes
  - Better understanding of actions or assessment factors
  - Data sources: EPA (AP-42), state websites, Google!
- **Peer-review with URS team and CRG support**

Sustainability Measurements

Natural Resources

- Energy
- Treatment Materials
- Water
- Land

Pollutants

- CO_2 (Fuel and degradation)
- NOx, SOx, VOCs, PM-10
- Water discharges
- Hazardous and Non-hazardous Waste

Exposure Hours

- Contractors
- Oversight

Sites and Remedies Evaluated

Bell Landfill

- Offsite GW Disposal
- Spray Irrigation
- Wetland

Carteret

- Dig & Haul
- Ex-Situ Treatment
- Capping

Reemay

- Pump and Treat
- Bio-stimulation

Chambers Works SWMU 8 – In progress

Example Sustainability Assessment: Managing Bell Landfill Leachate

Former industrial landfill
- 13 hectare
- Soil cap, grass
- 200 m^3/yr leachate

Current off-site disposal
- Leachate collection
- Every two weeks
- Transport (640 km)
- Disposal at POTW

Alternate technologies
- Constructed wetland
- Spray irrigation

A 640 Km Trip for Every Load of Leachate

Bell Landfill Technology Assessment

Technology	Energy Consumption	Resource Use	Releases to Environment
Off-site disposal	• Transportation - Disposal • Electricity - Pumping - Disposal	• Diesel fuel	• Carbon dioxide • Mobile-source pollutants • Fixed-source (electricity) pollutants
Constructed wetlands	• Construction - Holding cell - Wetlands • Electricity - Pumping	• Diesel fuel • Soil for holding cell	• Carbon dioxide (fuel less fixation) • Mobile-source construction equipment pollutants • Fixed-source (electricity) pollutants
Spray irrigation	• Construction - Holding cell - Spray field • Electricity - Pumping	• Diesel fuel • Soil	• Carbon dioxide (fuel less fixation) • Mobile-source construction equipment pollutants • Fixed-source (electricity) pollutants

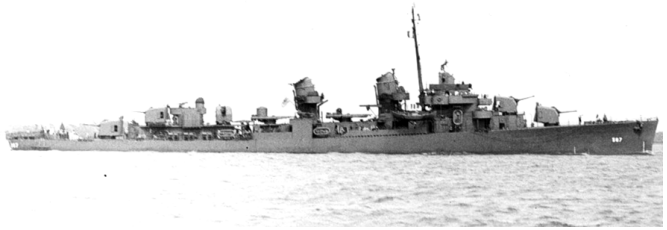
Bell Landfill Sustainability Metrics

Sustainability Metric	Offsite GW Disposal	Wetland	Spray Irrigation
Energy			
Fuel (GJ)	**(46,222)**	**(439)**	**(439)**
Resources			
H_2O (cubic meters)	**(5,734)**	**0**	**0**
Land (hectare)	**0**	**0**	**0**
Releases			
CO_2 (ton)	**610**	**(2,859)**	**(2,826)**
NOx (ton)	**97.3**	**1.6**	**1.7**
SOx (ton)	**8.4**	**0.1**	**0.1**
VOCs (ton)	**0.0**	**0.4**	**0.4**
PM-10 Fugitive (ton)	**748**	**0.4**	**0.4**
PM-10 Combustion (ton)	**7**	**0.1**	**0.1**
Sludge (ton)	**(0.1)**	**0.0**	**0.0**
Exposure Hours	**25000**	**2300**	**2300**

Bell_Methodology Development_08_31.xls

Equivalents of the Bell Landfill CO_2 Reduction

2,500 round trips to Europe



USS Bell DD-587 2,800 tons of steel

5,827,000 miles in Dave'sZ4

Fly 478,000 coconuts to England

Build 1,730 rabbits to throw at the English

Grow 39,400 shrubberies

Assessing Sustainability – Hypothetical Site X

Site Characteristics

- 0.5 Acre of BETX - 10 ft deep
- Groundwater elevation 2 ft BGS
- Soil hydraulic conductivity = 10^{-3} cm/sec
- GW Disposal – 1 well - 500 gpd
- BETX: 500 mg/kg treat to 50 mg/kg
- Transportation: Landfill and GW disposal, 100 mile RT
- Treatment: 0.5 lb/lb of BETX via geoprobe every other year for 5 years
- Source Biotreatment with geoprobe injection (4 per treatment)

Technologies

- Offsite Groundwater Disposal
- Source Removal
- Source Biotreatment

Offsite Groundwater Disposal

Natural Resources

- Energy
  - Install Wells
  - Pump GW
  - Disposal GW
- Water

Pollutants

- CO_2 (Fuel and degradation)
- NOx, SOx, VOCs, PM-10

Exposure Hours

- Contractors
- Oversight

Source Removal

Natural Resources

- Energy
  - Excavation
  - Hauling (Disposal and Backfill)
  - Support Equipment

Pollutants

- CO_2 (Fuel)
- NOx, SOx, VOCs, PM-10
- Non-Hazardous Waste

Exposure Hours

- Contractors
- Oversight

Source Biotreatment

Natural Resources

- Energy
  - Mob/demob (People, equipment, treatment materials)
  - Inject Treatment Materials
- Water

Pollutants

- CO_2 (Fuel and Degradation)
- NOx, SOx, VOCs, PM-10

Exposure Hour

- Contractors
- Oversight

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	Sustainability Measures	Offsite GW Disposal	Source Removal	Source Biotreatment
2	**Net**			
3	CO_2 (ton)	0	0	0
4	H_2O (ac-ft)	0.00	0.00	0.00
5	Land (ac)	0.00	0.00	0.00
6	Sludge (ton)	0.00	0.00	0.00
7	NOx (ton)	0.00	0.00	0.00
8	SOx (ton)	0.00	0.00	0.00
9	VOCs (ton)	0.00	0.00	0.00
10	PM-10 (ton)	0.00	0.00	0.00
11	Fuel (MMbtu)	0	0	0
12	Non-Hazardous Waste (ton)	0	0	0
13	Treatment Materials (gal)	0	0	0
14	Pollutant Remediation (lb/yr)	0	0	0
15	Exposure Hour (hr)	0	0	0
16	**Credit**			
17	CO_2 (ton)	0	0	0
18	H_2O (ac-ft)	0.00	0.00	0.00
19	Land (ac)	0.00	0.00	0.00
20	**Debit**			
21	CO_2 (ton)	0	0	0
22	NOx (ton)	0.00	0.00	0.00
23	SOx (ton)	0.00	0.00	0.00
24	VOCs (ton)	0.00	0.00	0.00
25	PM-10 Fugitive Particulates (ton)	0.00	0.00	0.00
26	PM-10 Combustion Particulates (ton)	0.00	0.00	0.00
27	H_2O (ac-ft)	0.00	0.00	0.00
28	Land (ac)	0.00	0.00	0.00
29	Non-Hazardous Waste (ton)	0.00	0	0.00
30	**Other Factor**			
31	Sludge (ton)	0	0	0
32	Fuel (MMbtu)	0	0	0
33	Treatment Materials (gal)	0	0	0
34	Pollutant Remediation (lb/yr)	0	0	0
35	Exposure Hour (hr)	0	0	0
36	Backfill Soil (cy)	0	0	0

Site X | Offsite GW Disposal | Source Removal | Source Biotreatment

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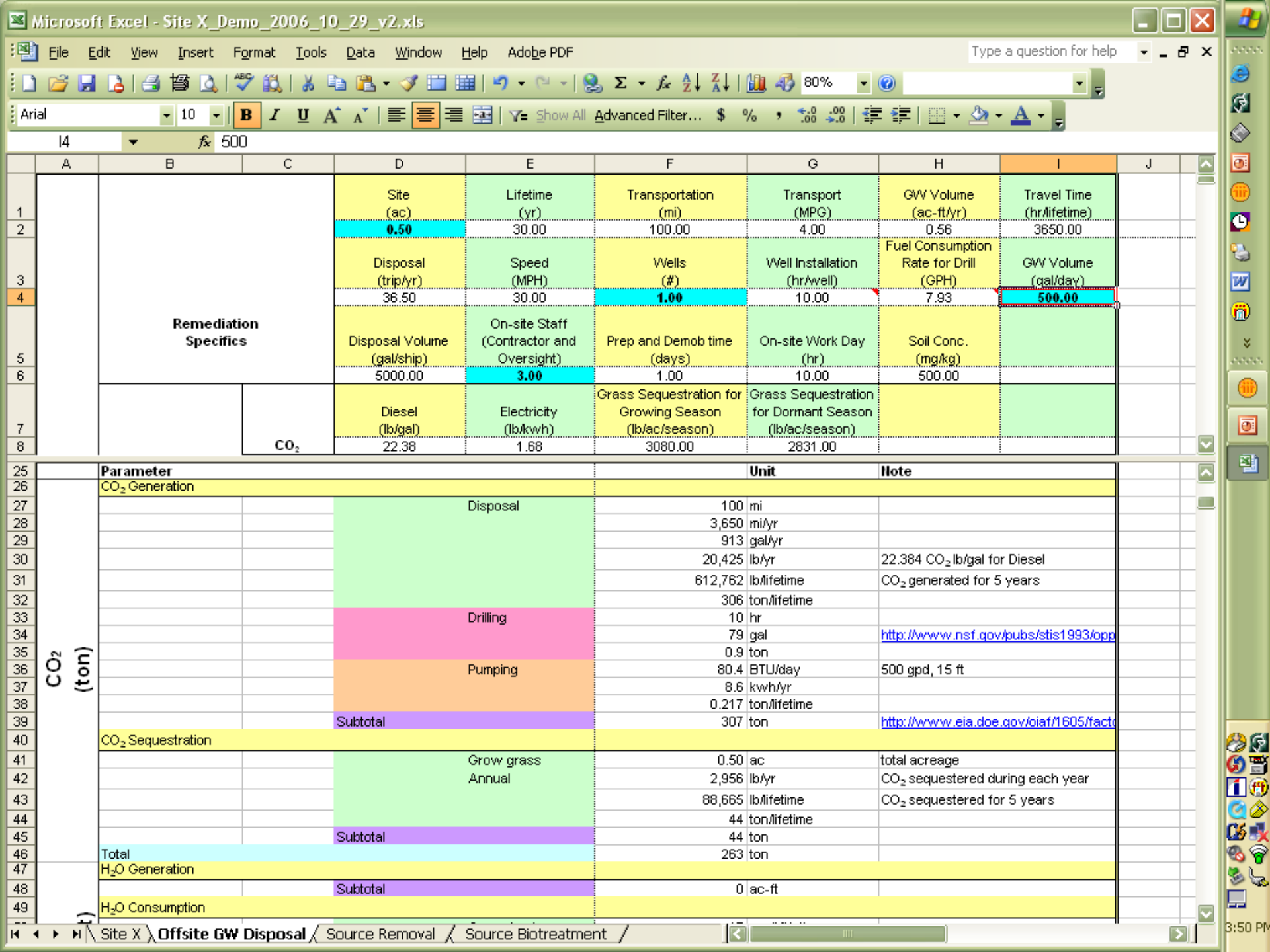

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	A	B	C	D	E	F	G	H	I	J
1				Site (ac)	Lifetime (yr)	Transportation (mi)	Transport (MPG)	GW Volume (ac-ft/yr)	Travel Time (hr/lifetime)	
2				0.50	30.00	100.00	4.00	0.56	3650.00	
3				Disposal (trip/yr)	Speed (MPH)	Wells (#)	Well Installation (hr/well)	Fuel Consumption Rate for Drill (GPH)	GW Volume (gal/day)	
4				36.50	30.00	1.00	10.00	7.93	500.00	
5		Remediation Specifics		Disposal Volume (gal/ship)	On-site Staff (Contractor and Oversight)	Prep and Demob time (days)	On-site Work Day (hr)	Soil Conc. (mg/kg)		
6				5000.00	3.00	1.00	10.00	500.00		
7				Diesel (lb/gal)	Electricity (lb/kwh)	Grass Sequestration for Growing Season (lb/ac/season)	Grass Sequestration for Dormant Season (lb/ac/season)			
8			CO_2	22.38	1.68	3080.00	2831.00			

		Parameter				Unit	Note
25							
26	CO_2 (ton)	CO_2 Generation					
27				Disposal	100	mi	
28					3,650	mi/yr	
29					913	gal/yr	
30					20,425	lb/yr	22.384 CO_2 lb/gal for Diesel
31					612,762	lb/lifetime	CO_2 generated for 5 years
32					306	ton/lifetime	
33				Drilling	10	hr	
34					79	gal	http://www.nsf.gov/pubs/stis1993/opp
35					0.9	ton	
36				Pumping	80.4	BTU/day	500 gpd, 15 ft
37					8.6	kwh/yr	
38					0.217	ton/lifetime	
39				Subtotal	307	ton	http://www.eia.doe.gov/oiaf/1605/facto
40		CO_2 Sequestration					
41				Grow grass	0.50	ac	total acreage
42				Annual	2,956	lb/yr	CO_2 sequestered during each year
43					88,665	lb/lifetime	CO_2 sequestered for 5 years
44					44	ton/lifetime	
45				Subtotal	44	ton	
46		Total			263	ton	
47		H_2O Generation					
48				Subtotal	0	ac-ft	
49		H_2O Consumption					

Site X | Offsite GW Disposal | Source Removal | Source Biotreatment

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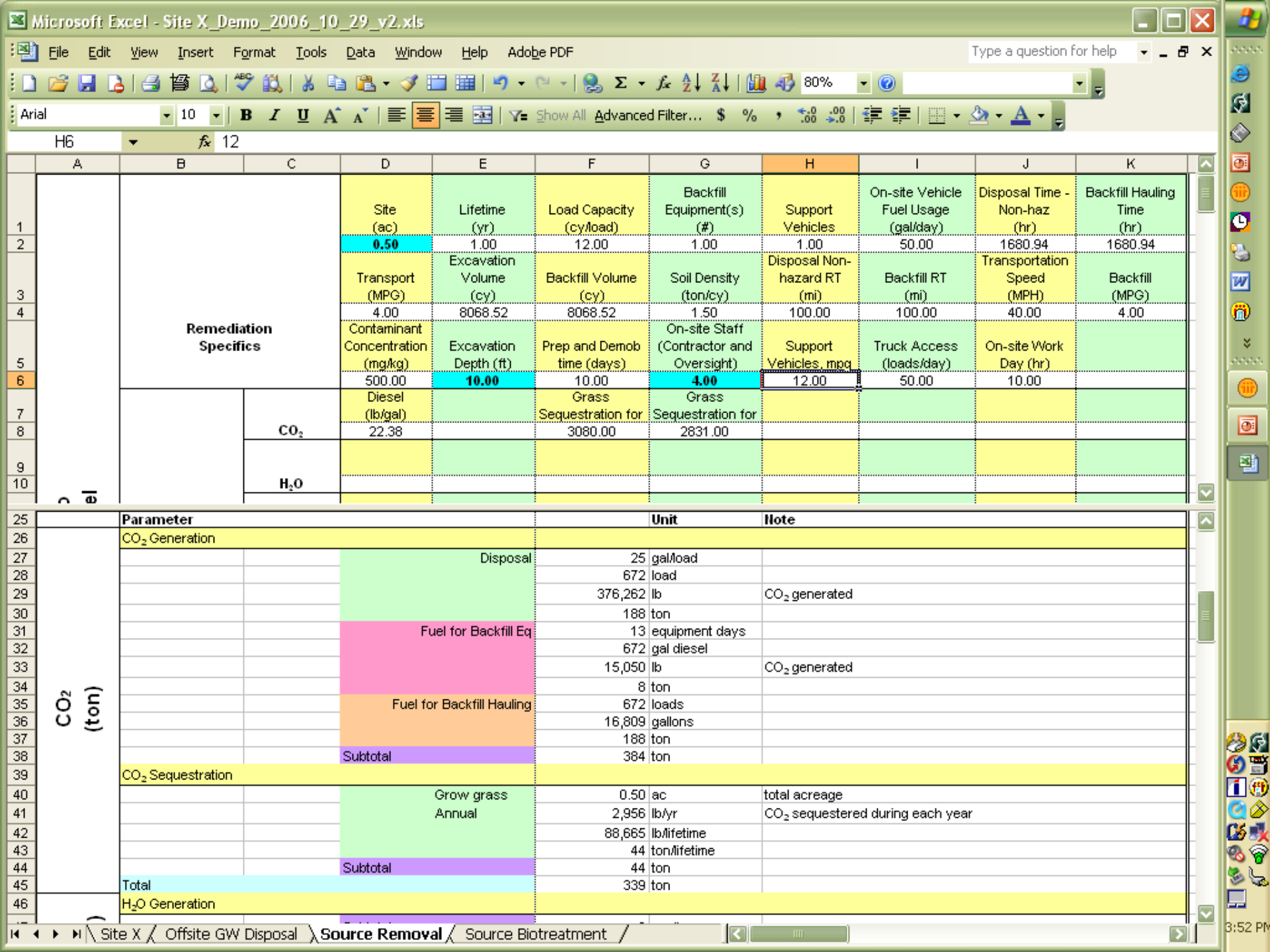

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	A	B	C	D	E	F	G	H	I	J	K
1				Site (ac)	Lifetime (yr)	Load Capacity (cy/load)	Backfill Equipment(s) (#)	Support Vehicles	On-site Vehicle Fuel Usage (gal/day)	Disposal Time - Non-haz (hr)	Backfill Hauling Time (hr)
2				0.50	1.00	12.00	1.00	1.00	50.00	1680.94	1680.94
3				Transport (MPG)	Excavation Volume (cy)	Backfill Volume (cy)	Soil Density (ton/cy)	Disposal Non-hazard RT (mi)	Backfill RT (mi)	Transportation Speed (MPH)	Backfill (MPG)
4				4.00	8068.52	8068.52	1.50	100.00	100.00	40.00	4.00
5		**Remediation Specifics**		Contaminant Concentration (mg/kg)	Excavation Depth (ft)	Prep and Demob time (days)	On-site Staff (Contractor and Oversight)	Support Vehicles, mpg	Truck Access (loads/day)	On-site Work Day (hr)	
6				500.00	**10.00**	10.00	**4.00**	12.00	50.00	10.00	
7				Diesel (lb/gal)		Grass Sequestration for	Grass Sequestration for				
8			CO_2	22.38		3080.00	2831.00				
9											
10			H_2O								

	A	B	C	D	E	F	G
25		**Parameter**				**Unit**	**Note**
26	CO_2 (ton)	CO_2 Generation					
27				Disposal	25	gal/load	
28					672	load	
29					376,262	lb	CO_2 generated
30					188	ton	
31				Fuel for Backfill Eq	13	equipment days	
32					672	gal diesel	
33					15,050	lb	CO_2 generated
34					8	ton	
35				Fuel for Backfill Hauling	672	loads	
36					16,809	gallons	
37					188	ton	
38				Subtotal	384	ton	
39		CO_2 Sequestration					
40				Grow grass	0.50	ac	total acreage
41				Annual	2,956	lb/yr	CO_2 sequestered during each year
42					88,665	lb/lifetime	
43					44	ton/lifetime	
44				Subtotal	44	ton	
45		Total			339	ton	
46		H_2O Generation					

Site X | Offsite GW Disposal | **Source Removal** | Source Biotreatment

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D36 Subtotal

	A	B	C	D	E	F	G	H	I
1				Site (ac)	Fuel Consumption Rate for Drill (GPH)	Support Truck RT (mi)	Support Truck (MPG)	Geoprobe Locations (#)	Stabilization Volume (cy)
2				**0.50**	7.93	100.00	12.00	**4.00**	8068.52
3		**Remediation Specifics**		Truck Ave. Speed (MPH)	Drill Rig RT (mi)	Pickup Truck RT (mi)	Pickup Truck (MPG)	Treatment (lb/lb)	Target Treatment (mg/kg)
4				40.00	100.00	100.00	8.00	0.50	450.00
5				Prep and Demob time (days)	Equipment Mobilized	Mob Distance (mile)	Daily Fuel Usage Avg (gal/day)	Work Duration (hr)	Number of Treatments
6				1.00	3.00	100.00	10.00	10.00	**3.00**
7				Diesel (lb/gal)	Monitor Well Locations (#)	Contaminant Depth (ft)	Well installation time and Treatment Time (hr/well)	Remedial Application (event/lifetime)	Soil Density (ton/cy)
8			CO_2	22.38	**1.00**	**10.00**	10.00	3.00	1.50
9					Water for Drilling (gal)	Water for Biotreatment (gal)	Soil Density (ton/cy)	Lifetime (yr)	On-site Staff (Contractor and Oversight)

		Parameter			Unit	Note
25						
26	CO_2 (ton)	CO_2 Generation				
27			Fuel for Transport	75	gal	
28				75	gal	
29				1,679	lb	22.384 CO_2 lb/gal for Diesel
30				0.8	ton	
31			Fuel for Drill	130	hr	
32				1,030	gal	http://www.nsf.gov/pubs/stis1993/opp931
33				11.53	ton	
34			Subtotal	12.37	ton	http://www.eia.doe.gov/oiaf/1605/factors.h
35		CO_2 Sequestration				
36			Subtotal	44	ton	
37		Total		-32	ton	
38	H_2O (ac-ft)	H_2O Generation				
39			Subtotal	0	ac-ft	
40		H_2O Consumption				
41			Monitoring Well	100	gal	Monitoring Well
42			Biotreatment	12,000	gal	Bio treatment
43			Subtotal	0.004	ac-ft	
44		Total		0.004	ac-ft	
45	Land (ac)	Land Generation				
46			Subtotal	0.50	ac	
47		Land Consumption				
48			Subtotal	0	ac	
49		Total		0.50	ac	

Site X | Offsite GW Disposal | Source Removal | Source Biotreatment

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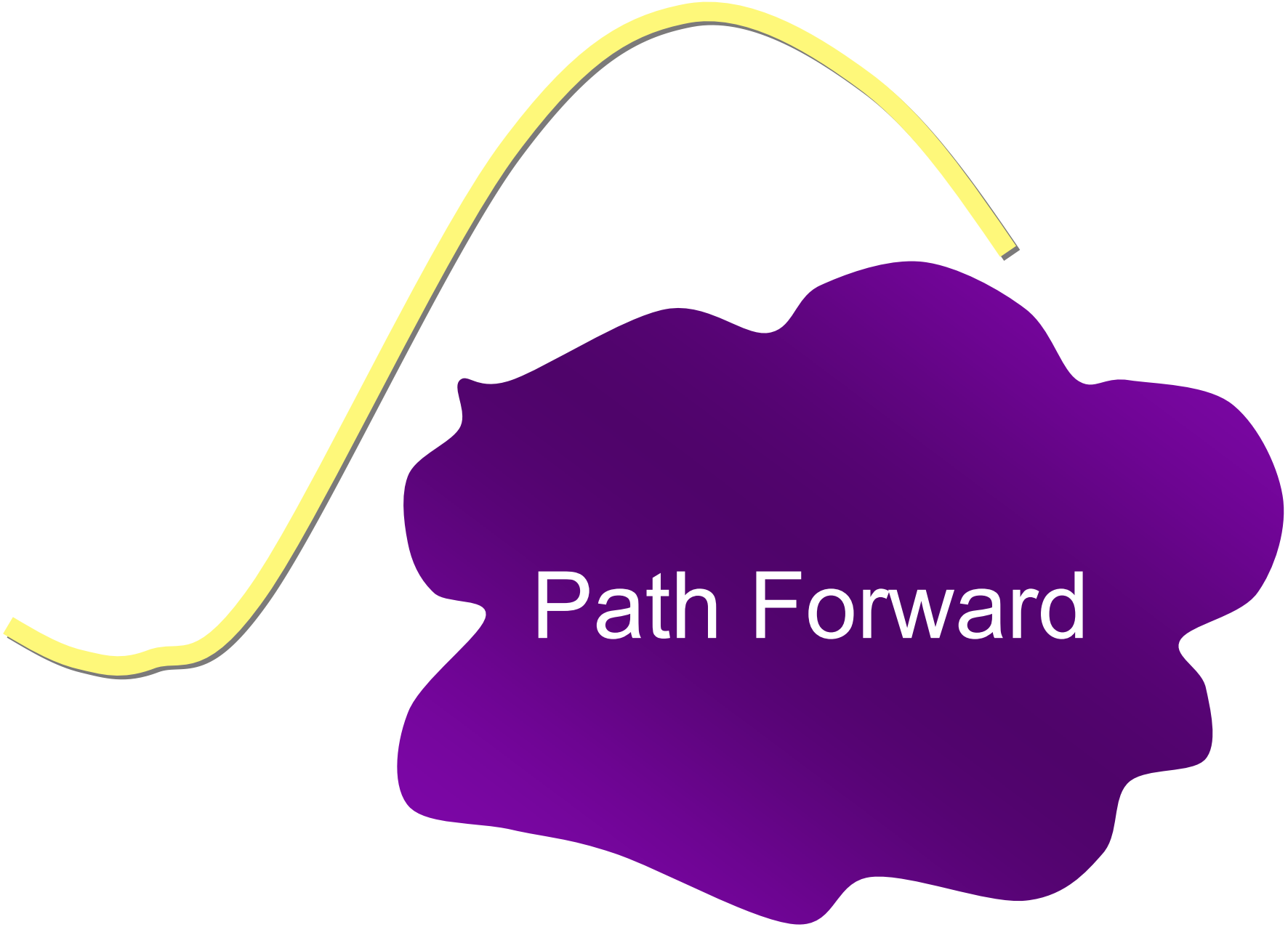
	Sustainability Measures	Offsite GW Disposal	Source Removal	Source Biotreatment
2	**Net**			
3	CO_2 (ton)	263	339	(32)
4	H_2O (ac-ft)	(16.87)	0.00	0.00
5	Land (ac)	0.00	0.50	0.50
6	Sludge (ton)	0.00	0.00	0.00
7	NOx (ton)	8.41	10.50	0.34
8	SOx (ton)	0.73	0.91	0.03
9	VOCs (ton)	0.08	0.70	0.00
10	PM-10 (ton)	0.59	0.74	0.03
11	Fuel (MMbtu)	3,797	4,756	153
12	Non-Hazardous Waste (ton)	0	12,103	0
13	Treatment Materials (gal)	0	0	5,446
14	Pollutant Remediation (lb/yr)	458	12,103	2,179
15	Exposure Hour (hr)	3,710	4,300	0
16	**Credit**			
17	CO_2 (ton)	44	44	44
18	H_2O (ac-ft)	0.00	0.00	0.00
19	Land (ac)	0.00	0.50	0.50
20	**Debit**			
21	CO_2 (ton)	307	384	12
22	NOx (ton)	8.41	10.50	0.34
23	SOx (ton)	0.73	0.91	0.03
24	VOCs (ton)	0.08	0.70	0.00
25	PM-10 Fugitive Particulates (ton)	0.00	0.00	0.00
26	PM-10 Combustion Particulates (ton)	0.59	0.72	0.03
27	H_2O (ac-ft)	16.87	0.00	0.00
28	Land (ac)	0.00	0.00	0.00
29	Non-Hazardous Waste (ton)	0.00	12,103	0.00
30	**Other Factor**			
31	Sludge (ton)	0	0	0
32	Fuel (MMbtu)	3,797	4,756	153
33	Treatment Materials (gal)	0	0	5,446
34	Pollutant Remediation (lb/yr)	458	12,103	2,179
35	Exposure Hour (hr)	3,710	4,300	0
36	Backfill Soil (cy)	0	8,069	0

Site X | Offsite GW Disposal | Source Removal | Source Biotreatment

3:56 PM


Path Forward

Long Term Plans for Sustainability

Track CRG's sustainability assessments

Track the remedies chosen and sustainability impacts to understand the impact of sustainability analysis

Periodically adjust our strategies until we believe we have optimized our process

Engage the outside world

Pending Sustainability Evaluations

Chambers Works – SWMU 8

Waste

- Soil Capping
- Excavation and on-site Landfill
- Aerobic Bioventing

Ground Water

- DNAPL Recovery
- Shallow Slurry Wall
- Deep Slurry Wall
- Aerobic Biosparging
- Anaerobic Biostimulation

2007 Sustainability Assessments

Feasibility Studies

- Barnam Avenue
- Ch Wks Salem Canal
- Louisville
- Louviers SWMU 20/24
- New Haven
- Pompton Lakes Delta
- Repauno NB Area
- Tecumseh Leachate
-

Possible

- Grasselli Site-wide
- Rochester Driving Park
-

Cost Estimates vs Sustainability Assessments

What technologies do we still need to assess?

Modules Available (January 1, 2007)

- **Constructed Wetlands**
- **Dig and Haul**
- **In-situ Aerobic Stimulation**
- **In-site Anaerobic Stimulation/Augment**
- **Ex-situ Stablilization**
- **Off-site GW Disposal**
- **On-site GW Disposal**
- **Off-site Haz Waste Disposal**
- **Off-site Wast Disposal**
- **On-site Haz Waste Landfill**
- **Slurry Wall**
- **Soil Cover**
- **Spray Irrigation**

What others do we need to assess?

- PRB
- Other in-situ treatments
  -
  -
  -
- Sediment
  - Removal
  - Treatment
  - Cover
- Soil Washing
- Others
  -
  -
  -


Open Discussion